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ABSTRACT

Piaget has suggested formal operations, as measured by his tasks, may be related specifically to physics-type problem solving and that other hypothetico-deductive thinking processes develop in adults in other specializations. The present follow-up study examined the relationship between formal versus concrete operational thinking as measured by two tasks (Chemical Mixing and Shadow) and academic performance of 46 science/mathematics majors (22 females, 24 males) versus other majors in three course categories: mathematics, science, and all courses combined. Science/mathematics majors made significantly higher mean grades in all three course categories. No significant differences between academic performance of concrete and formal operational groups were found when operational level was determined solely by performance on either the Chemical Mixing (determined by a verbal process) or the Shadow task (determined by a manipulative procedure. However, when the two performances were combined to determine operational level, formal subjects had significantly higher mean grades in mathematics/statistics. Significant sex x operational level and major x operational level interactions suggested that formal operations involved in the Shadow task is a positive factor for males but not for females, and that this type of formal operations may have a positive effect on mathematics grades of science/mathematics majors and a negative effect on mathematics grades of other majors. (Author/BL)

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Differences in Grade Point Averages of Male and Female College Students Having Different Majors and Piagetian Operational Levels

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Running head: DIFFERENCES IN GRADE POINT AVERAGES

Abstract

Piaget (1972) has suggested formal operations, as measured by his tasks, may be related specifically to physics-type problem solving and that other hypothetico deductive thinking processes develop in adults in other specializations. The present follow-up study examined the relationship between formal versus concrete operational thinking as measured by two tasks (Chemical Mixing and Shadow) and academic performance of science/mathematics majors versus other majors in three course categories: mathematics, science, and all courses combined. Science/mathematics majors made significantly higher mean grades in all three course categories. No significant differences between academic performance of concrete and formal operational groups were found when operational level was determined solely by performance on either the Chemical Mixing (determined by a verbal process) or the Shadow task (determined by a manipulative procedure). However, when the two performances were combined to determine operational level, formal subjects had significantly higher mean grades in mathematics/statistics. Significant sex x operational level and major x operational level interactions suggested that formal operations involved in the Shadow task is a positive factor for males but not for females and that this type of formal operations may have a positive effect on mathematics grades of science/mathematics majors and a negative effect on mathematics grades of other majors.

Differences in Grade Point Averages of Male and Female College Students Having Different Majors and Piagetian Operational Levels

Researchers have consistently found that the majority of adults, including college students, give concrete responses to Piagetian tasks (See Neimark, in Wolman, 1982, for a review of the findings). When sex differences have been found, a greater proportion of males have been categorized as "formal operational" (Dulit, 1972). Because not all adults attain formal operations, the validity of the concept of formal operations as a developmental process has been questioned. In response to this criticism, Piaget (1972) has defended his contention that formal operations is the final intellectual accomplishment. As the most probable explanation for the nonuniversality of the attainment of formal operations, he hypothesized that all normal adults acquire formal operations in the area of their specialization, though not necessarily in the physics-type thinking involved in the Piagetian tasks.

While Piaget's conjecture is intriguing, evidence to support it is sparse. Commons, Miller, and Kuhn (1982) have provided some evidence to suggest that his contention may be valid. They conducted a follow-up study of college freshmen matched on American College Test scores and found that formal operational students completed significantly more science/mathematics courses and earned significantly higher grade point averages in those courses than

concrete operational students. Significant differences were not found between the groups in their grades in liberal arts/social science courses, activities/vocational courses, or total courses completed during their first two years. Although these data lend support to the specific relationship of formal operations to science and mathematics, as Piaget hypothesized, Commons et al. (1982) used a group administered test which measured only isolation of variables. In addition, they selected their sample from a large pool of subjects, and using American College Test Scores as an ability measure, they matched each subject who scored formal operations on the two tasks administered with one who scored concrete operational on both tasks.

Although the Commons et al. (1982) study was carefully done, several questions remain to be answered. Do formal operational students earn higher grades in both mathematics and science courses or in only one of the categories? Will similar results be found when formal operations is measured by the usual Piagetian procedures and involves operations other than isolation of variables? Will the relationship between formal operations and academic performance in mathematics and science be found when the formal operations category includes subjects whose responses give evidence of formal operations? The present follow-up study was designed to answer those questions.

Method

Subjects

Sixty students enrolled in an introductory calculus class (30 males and 30 females) served as volunteer subjects. Each gave permission to secure information from their academic records. For this follow-up study, 22 females and 24 males who had either graduated or were still enrolled constituted the sample. The other 14 subjects had dropped out of school or had transferred to another institution.

Procedures

In the Fall Semester, 1979, two Piagetian tasks, Chemical Mixing and Projection of Shadows, were administered. The Chemical Mixing (Chem) task, which requires the subject to find the correct combination of clear liquids to produce a colored liquid, was administered by a verbal procedure described by Dulit (1972). The Projection of Shadows (Shadow) task was administered by the Piagetian (1958) procedure requiring the correct placement of rings to form the same sized shadow. In both procedures, the subject must state the principle involved in the solution. Each response was scored as Concrete, Transitional, or Formal by the procedures described by Dulit (1972).

In the Fall Semester, 1982, the following information was secured from each student's individual academic record: major (science or mathematics versus other); and grade point average in

physics and chemistry (GPA-Sc), grade point average in mathematics and statistics (GPA-Math), and cumulative grade point average (GPA-Cum).

Analysis

Using sex, operational level (concrete versus transitional and formal), and major (science/mathematics versus other) as subject variables, a 2 x 2 x 2 analysis of variance was performed on each grade point average (GPA-Sc, GPA-Math, and GPA-Cum). A separate analysis was used for the categorization of operational level using the Chem, Shadow, and combination of the two tasks.

Results

The results of the analyses of variance are presented in Table 1 for all main effects and the two way interactions involving operational level. The most obvious finding involves the grade point average differences between Science/Math majors and Other majors. In all instances Science/Math majors had higher grade point averages than Other majors.

Of greatest interest is the fact that operational level significantly distinguished between grade point averages only when it was measured by the Shadow task or entered into the categorization. As Table 1 shows, the only Operational Level F-value significant at the .05 level was obtained in the analysis of GPA-Math in the Combined Categorization of formal and concrete

operational functioning (F = 4.588). The Formal group had mean GPA-Math of 2.58 in comparison to 2.05 of the Concrete group.

When the interactions are examined, there is a suggestion that formal operations is related to performance of mathematics and science majors and is more relevant for males than females. As Table 1 shows, the Shadow categorization resulted in a Sex and Operational level interaction on GPA-Cumulative (F = 4.411, p < .05). Males and females in the formal operational group had average grade point averages of 2.91 and 2.93 respectively, and their concrete counterparts had average grade point averages of 2.48 and 3.00 respectively. The significant Major x Operational Level interaction (F = 7.638, p < .01) revealed that Math/Science majors in the formal operational group had a mean grade point average of 3.23 in comparison to 2.34 earned by those in the concrete operational group. Other majors in the formal operational group had a mean grade point average in mathematics/statistics of 1.71 in comparison to 2.06 to other majors in the concrete operational group.

Conclusions

The present study suggests that other factors, such as major, maybe more salient influences upon grade point average but that operational level may be related to performance if it is measured by the Piagetian method. The relationships may not, however, be simple, as the interactions suggest. If formal operations are

related to higher grades only in mathematics, or primarily in mathematics, one may conclude that it is a measure of hypothetico deductive reasoning which is specific to performance in mathematics and not to chemistry and physics. One could hypothesize that formal operational thinking is prerequisite to satisfactory performance in physics and chemistry; however, the present study lends no support to that hypothesis. Perhaps, as Piaget suggests, there is another type of formal operations which is specific to each of the sciences.

Commons et al. (1982) found that subjects functioning at the formal operational stage earned higher mathematics/science grades, but in other course categories, relatively equal grades to those functioning at the concrete stage were earned. The present study, which had a more protracted follow-up period, suggests a slight advantage for formal operational subjects over concrete operational ones in cumulative grade point average. Since the Commons et al.'s study used a combined category for mathematics and science, it could be that the differences reported resulted from higher mathematics grades. On the other hand, Commons et al.'s procedure of matching on American College Test scores may have resulted in a more equivalent sampling and a more reliable finding.

The finding which suggest that formal operations lead to higher academic performance for science and mathematics majors but to lower performance for other majors is difficult to explain. One hypothesis might be that individuals at the formal operational stage

are frustrated when they employ the hypothetico deductive thinking process in nonproblem solving learning, especially when the majority of their courses require the problem-solving type of thinking. On the other hand, formal operational persons could place primary emphasis on learning principles involved in the courses other than mathematics and science, a process which could depress their grades but not necessarily their understanding; however, concrete operational individuals could earn higher grades. It is equally difficult to explain why formal operations are helpful to males but not to females. The most likely explanation appears to be that females may use a different process so that their performance in academic subjects is unrelated to formal operational thinking.

Since little research has been directed toward establishing the practical significance of formal operations or toward finding other measures of formal operations specific to a particular type of intellectual performance, these areas are fruitful ones for future research.

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Table 1

Results of Analyses of Variance (Sex X Operational Level X Major) on Grade Point Averages

Variable	Main Effects			Interactions	
	Sex(S)	Operational Level(O)	Major(M)	S X O	M X O
Chemical Categorization					
GPA-Chemistry & Physics	.015	.202	3.258	.527	.031
GPA-Mathematics and Statistics	.771	.677	8.087**	.212	.006
GPA-Cumulative	1.728	.380	5.770*	.075	.592
Shadows Categorization					
GPA-Chemistry & Physics	.001	1.920	4.006	3.680	.052
GPA-Mathematics and Statistics	1.751	1.796	12.730***	.052	7.638**
GPA-Cumulative	3.36	3.48	9.10**	4.411*	2.596
Combined Categorization					
GPA-Chemistry & Physics	.002	.875	3.007	3.962	.000
GPA-Mathematics and Statistics	1.919	4.588*	9.003**	.104	1.736
GPA-Cumulative	3.130	3.254	6.365*	2.427	.991

df = 1, 38. *$p < .05$. **$p < .01$. ***$p < .001$.